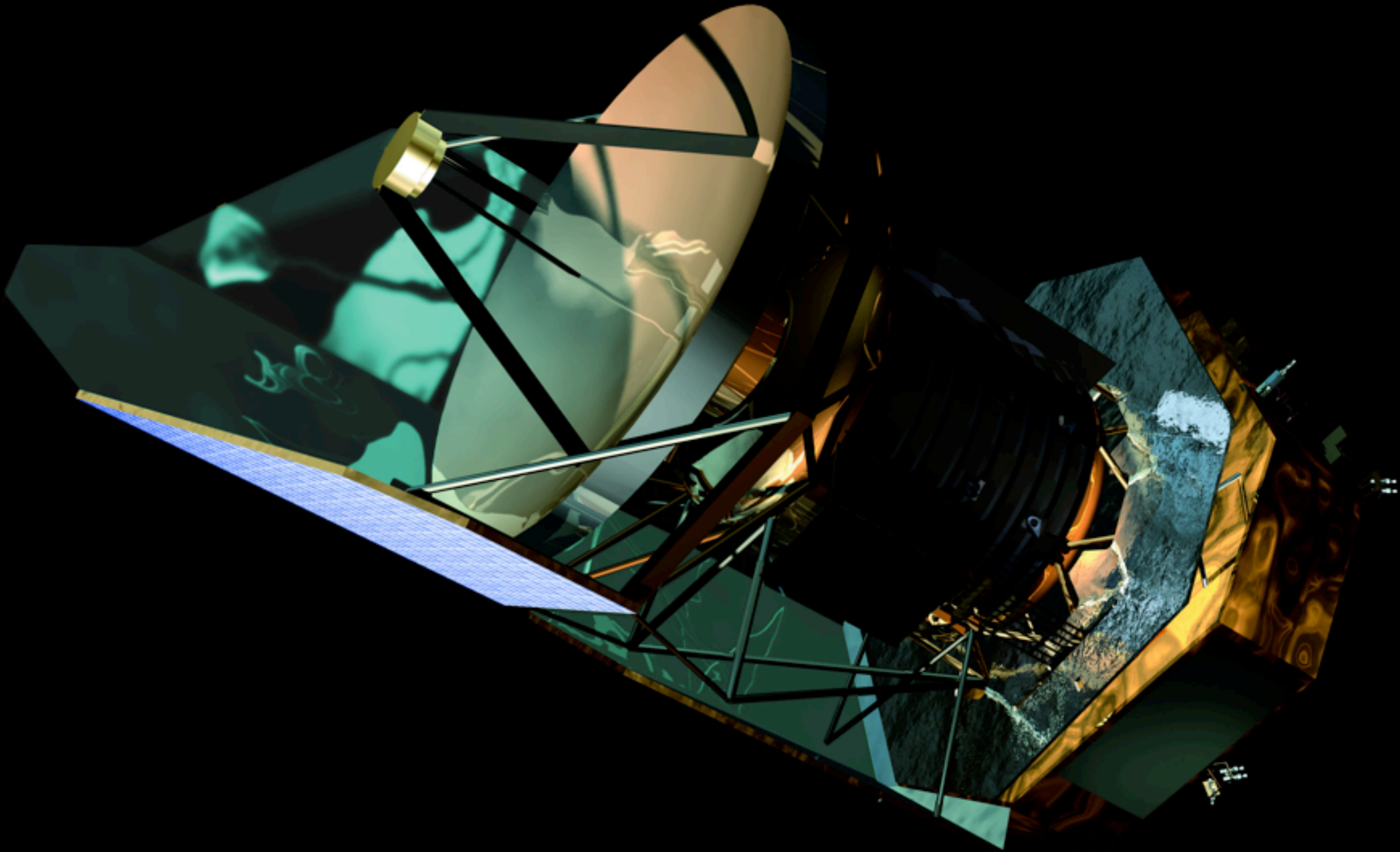
Vertical transport of water ice

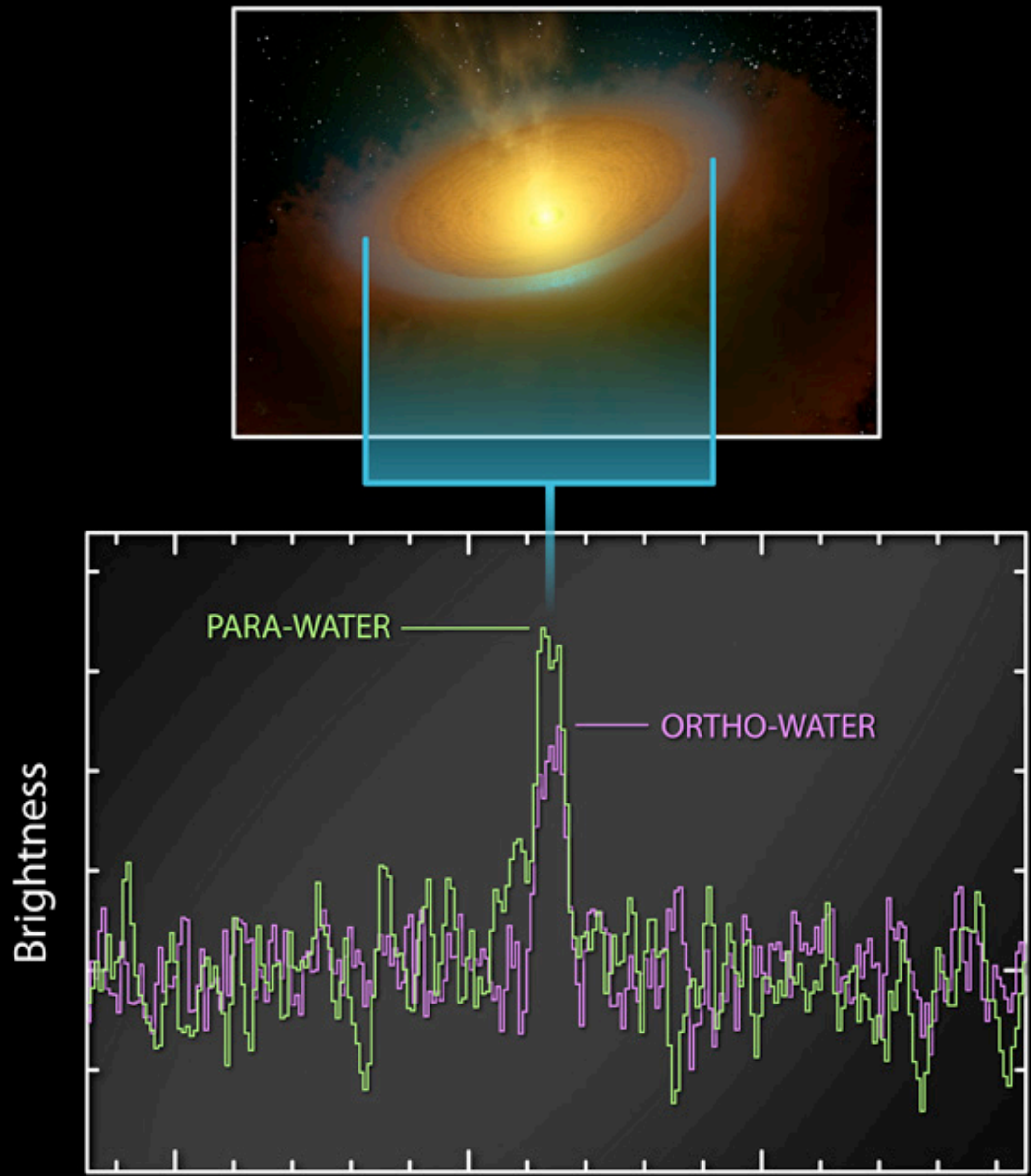
Carsten Dominik
University of Amsterdam

Kees Dullemond
Heidelberg University

The Herschel Space Telescope

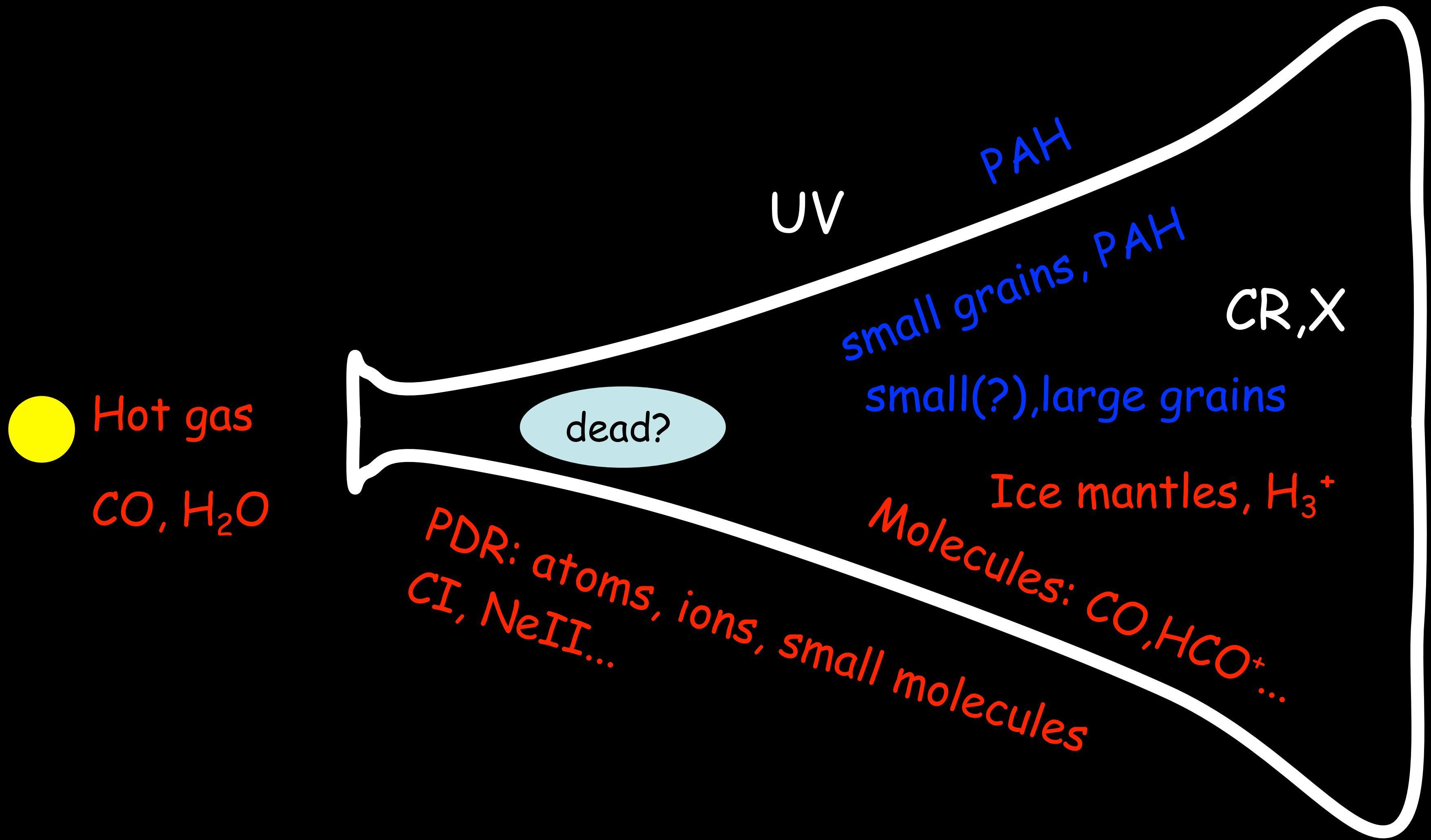


TW Hya observation



Hogerheijde et al 2011

Dust, Gas, Radiation



The relevant processes

photo desorption

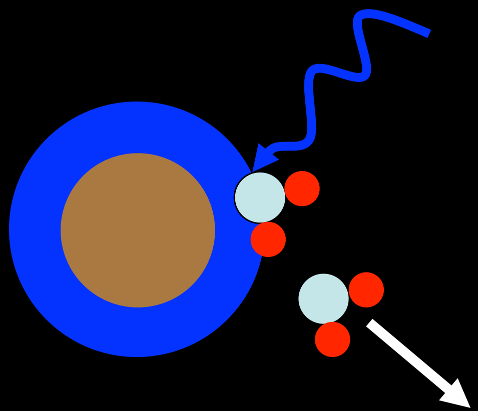
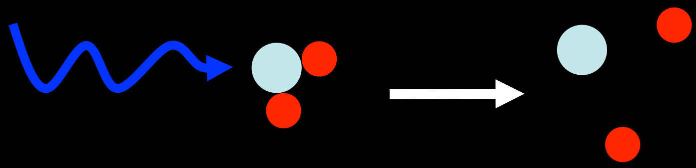
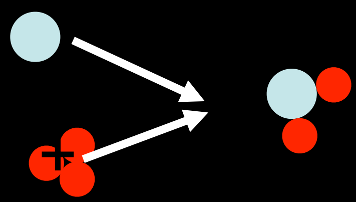


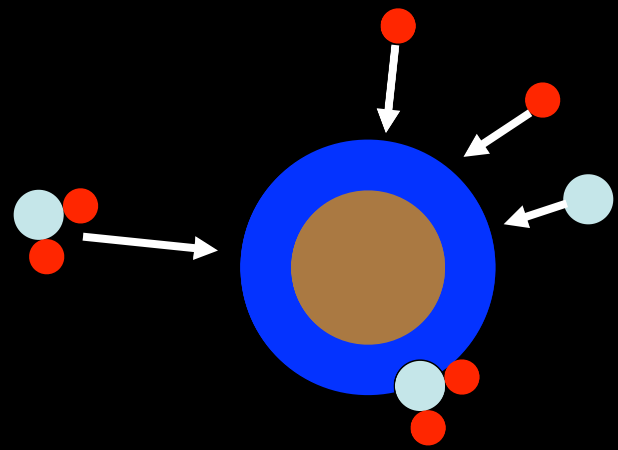
photo dissociation



gas phase formation route

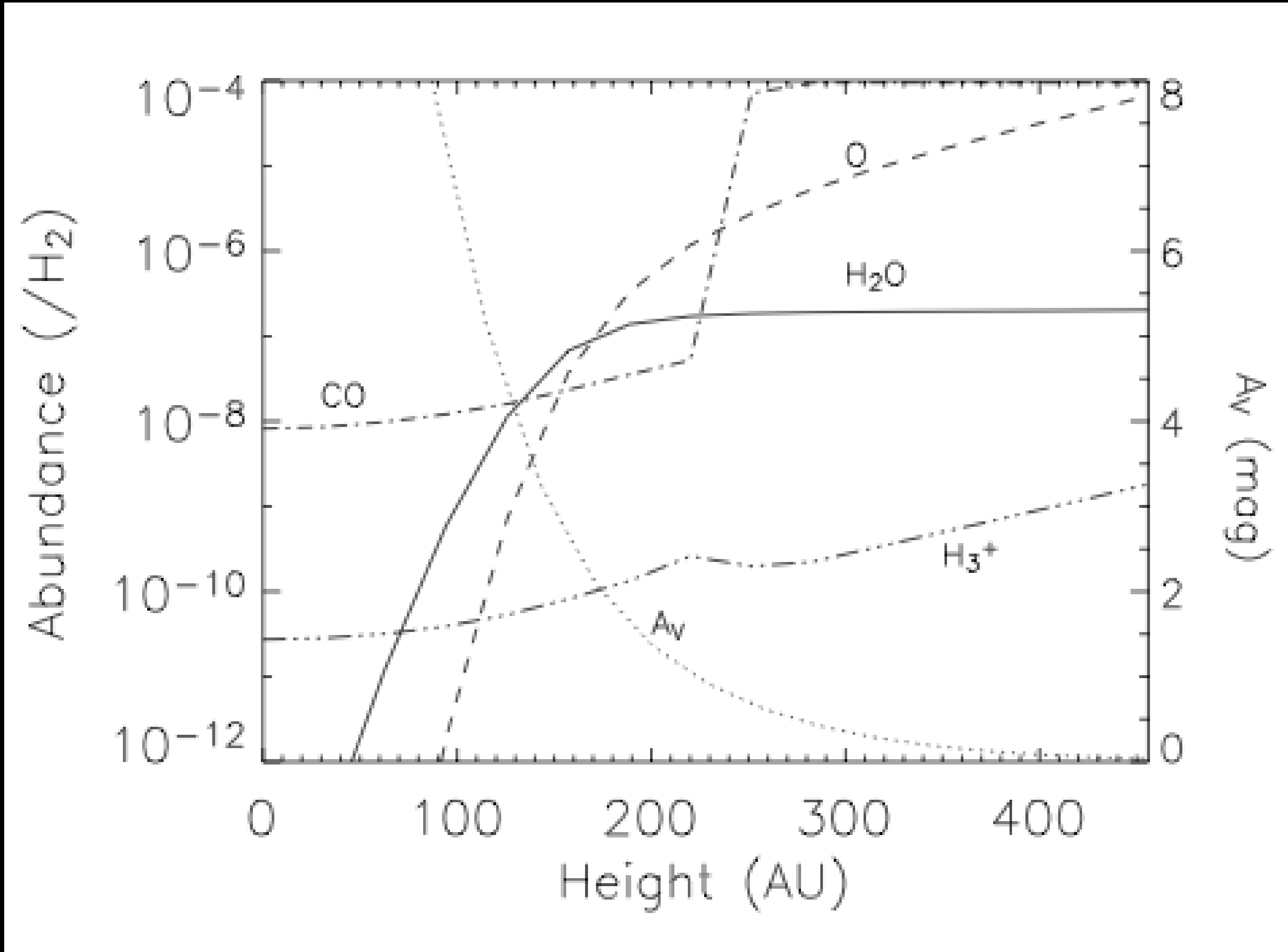


freeze-out/reformation



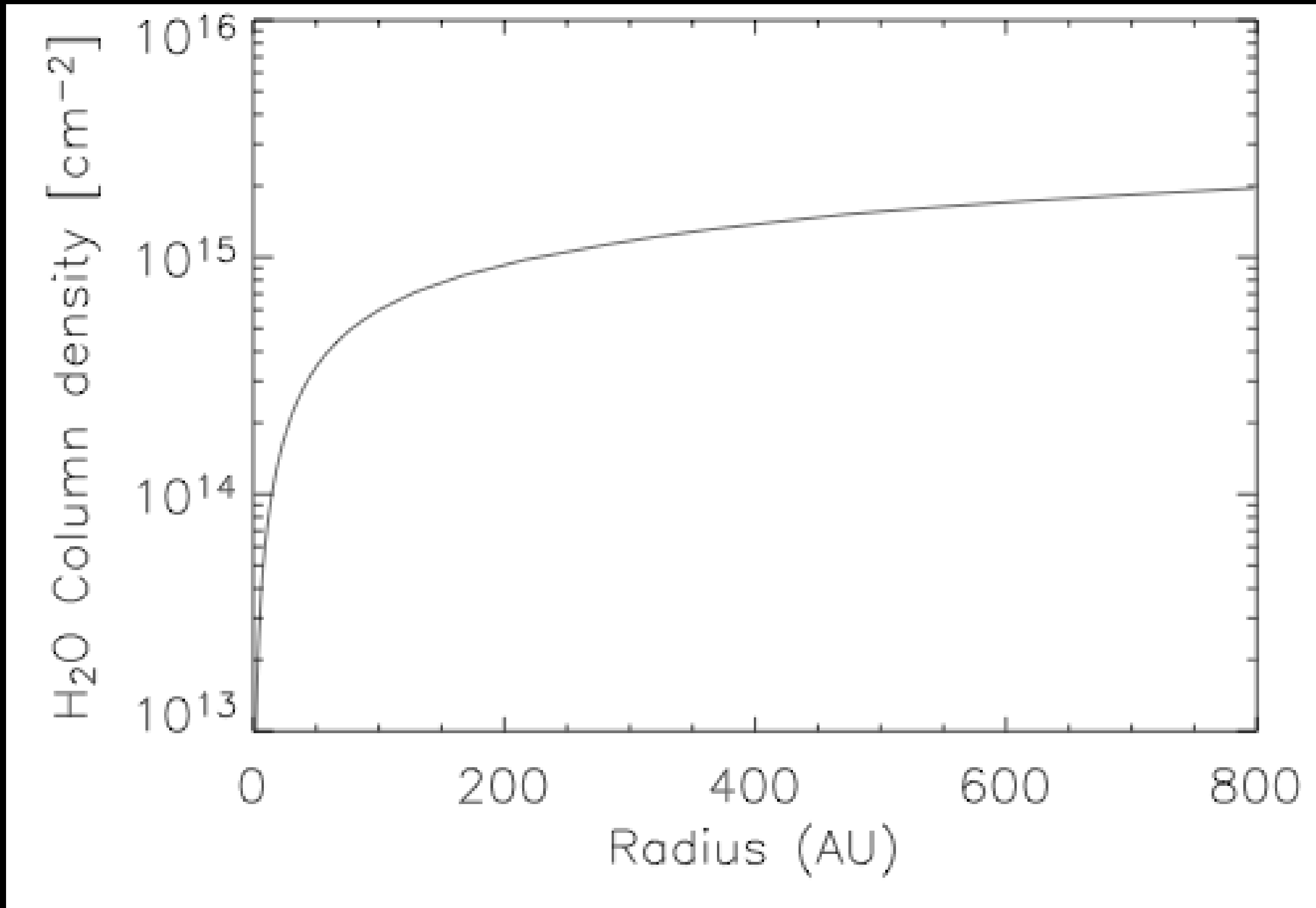
Dominik et al 2005

A cut through the PDR



Dominik et al 2005

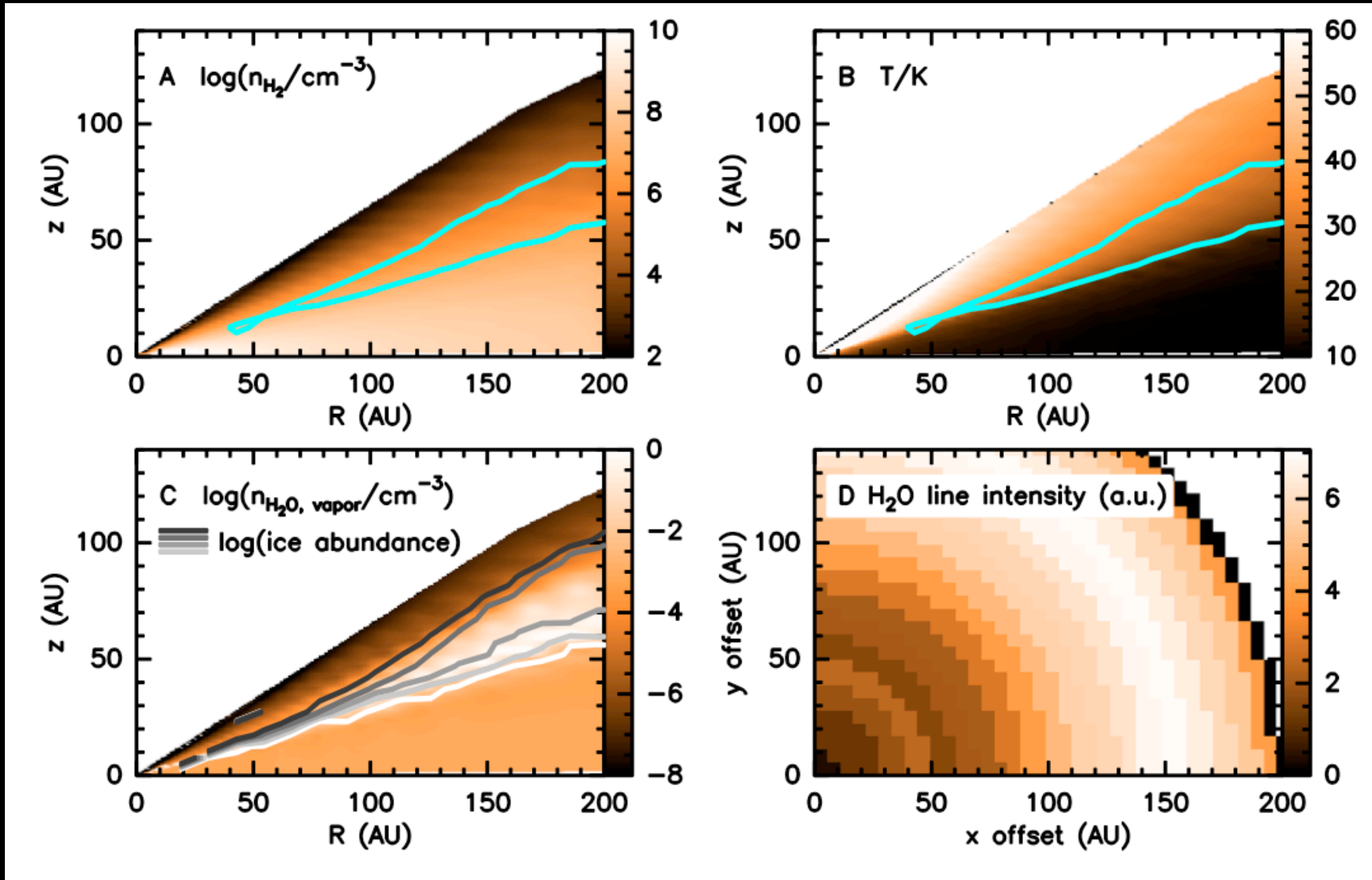
H_2O column density across the disk



Predicted H_2O column density ~3×10^{15} cm^{-2}

Dominik et al 2005

TW Hya model (Hogerheijde et al)

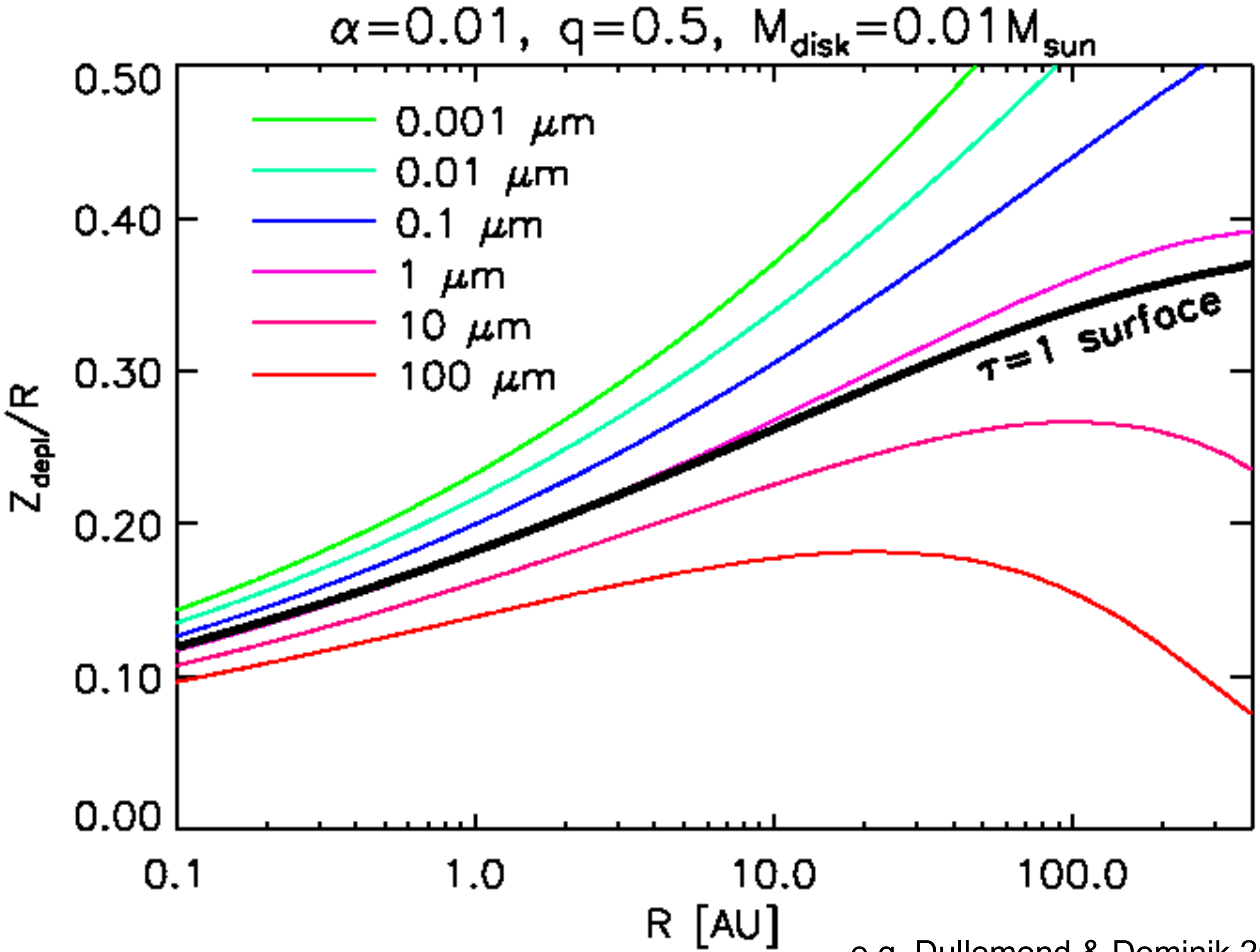


Predicted H_2O column density ~$3x10^{15}cm^{-2}$

Effects of vertical mixing

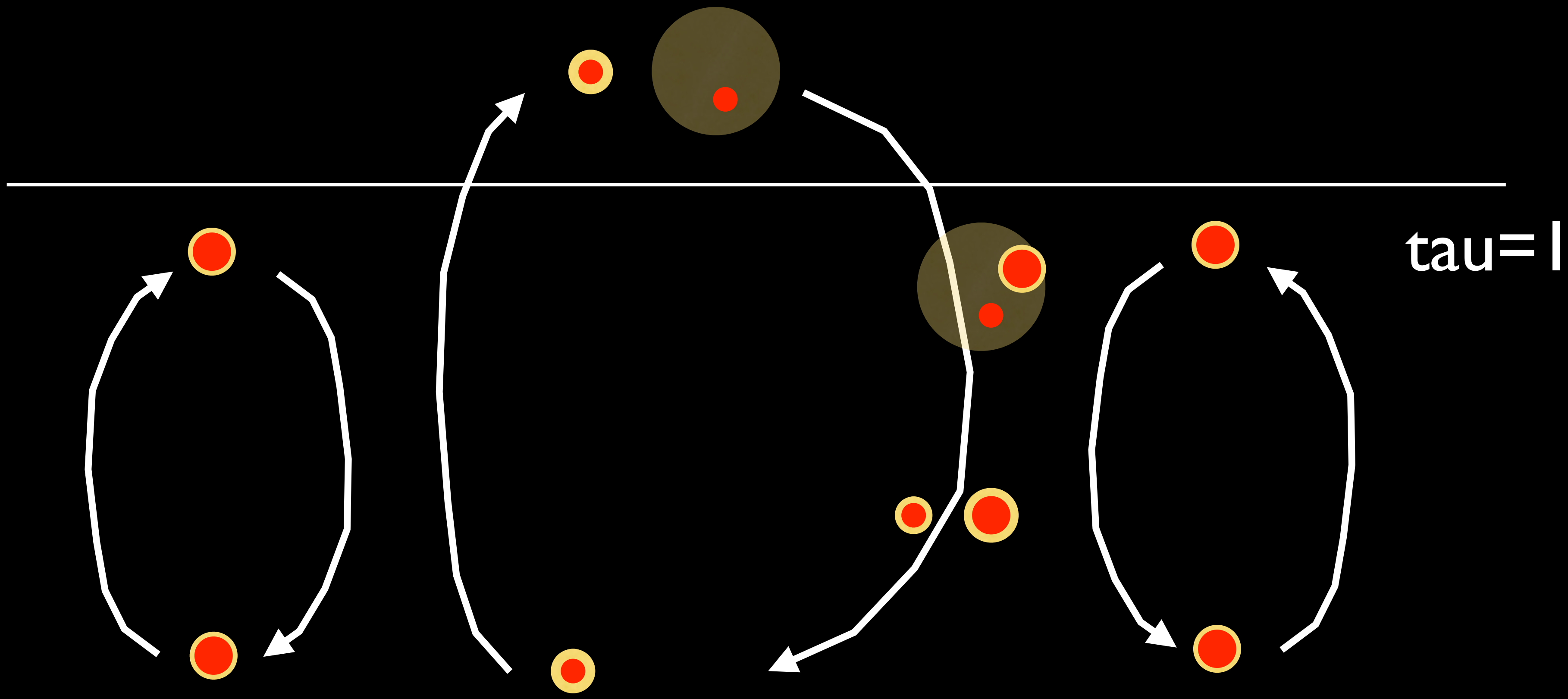
- Vapor-rich and vapor-poor gas is exchanged accross the tau=1 surface
- Grains move through the tau=1 surface. But not all grains!

Settling below τ=1: strong mixing case

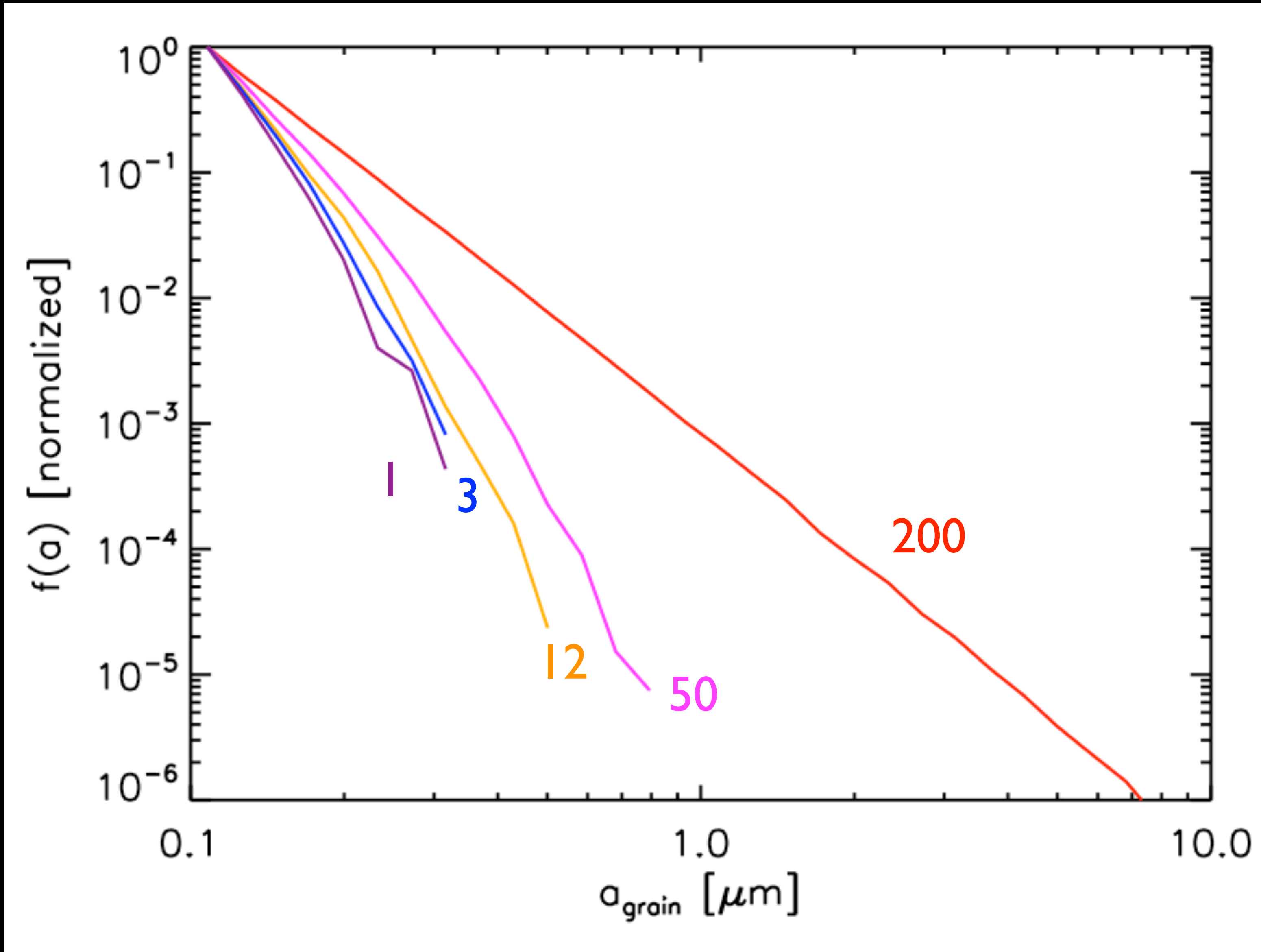


e.g. Dullemond & Dominik 2004

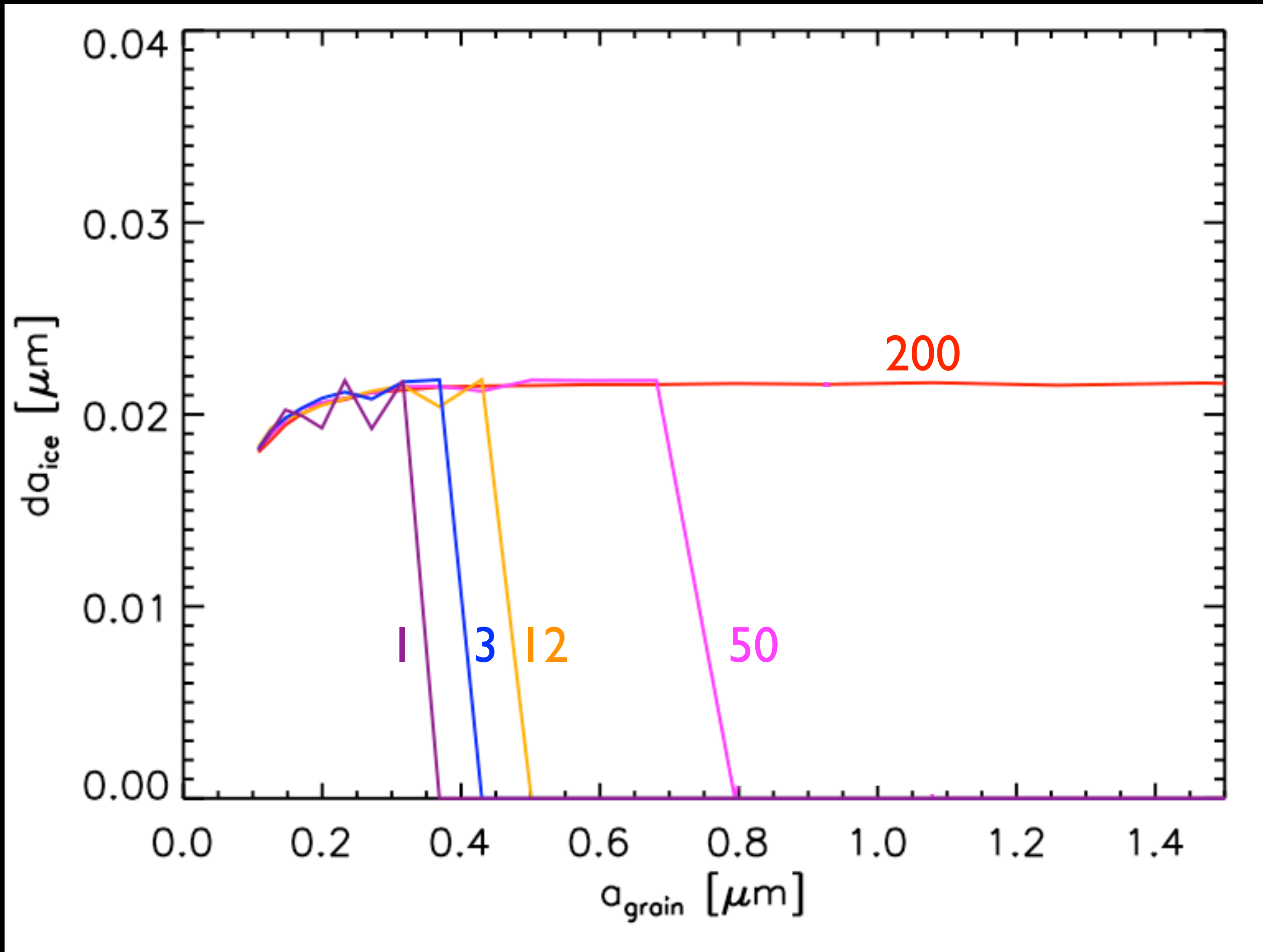
Pumping water



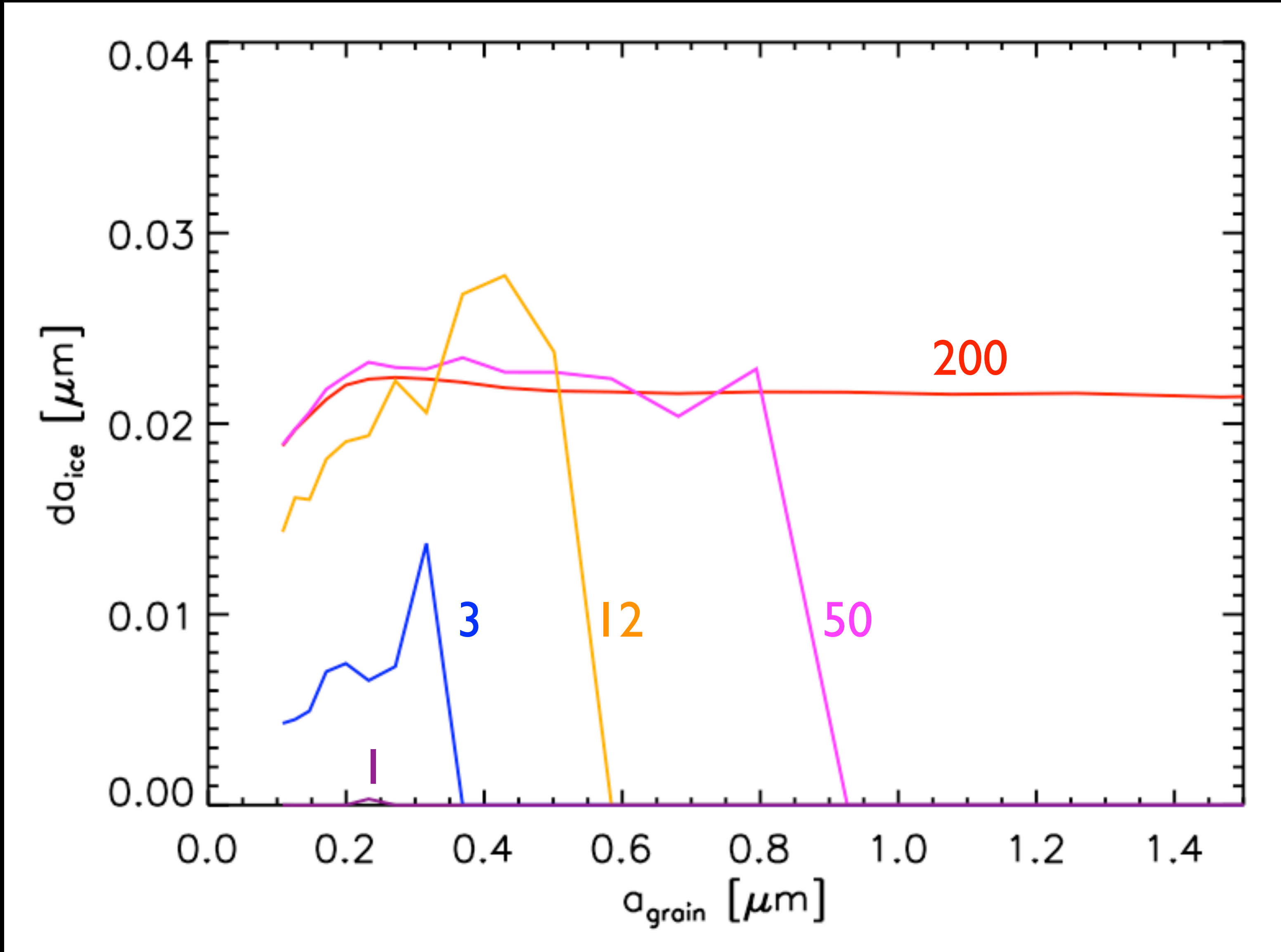
Size distribution at different heights



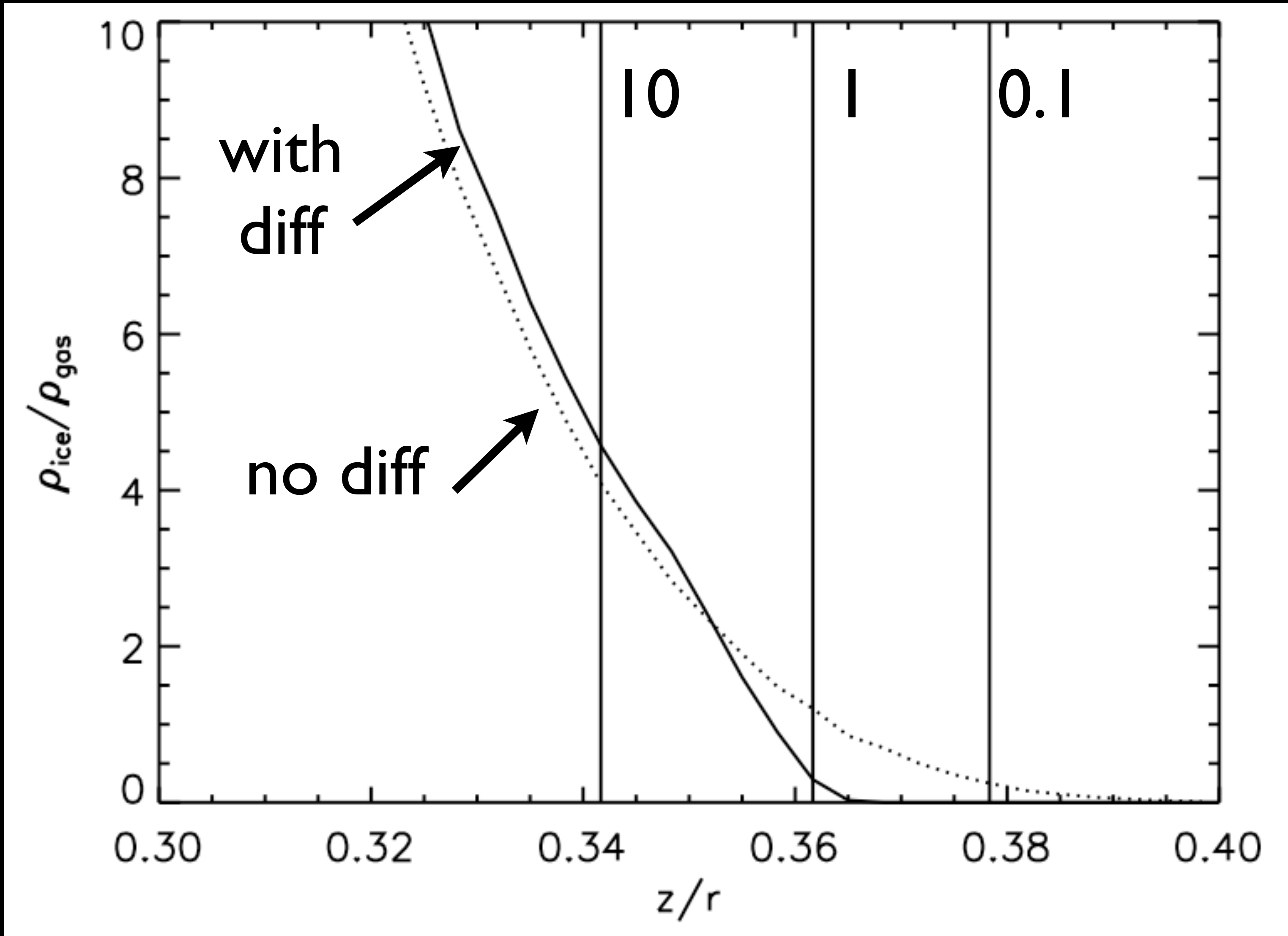
Ice layer on the grains: No diffusion



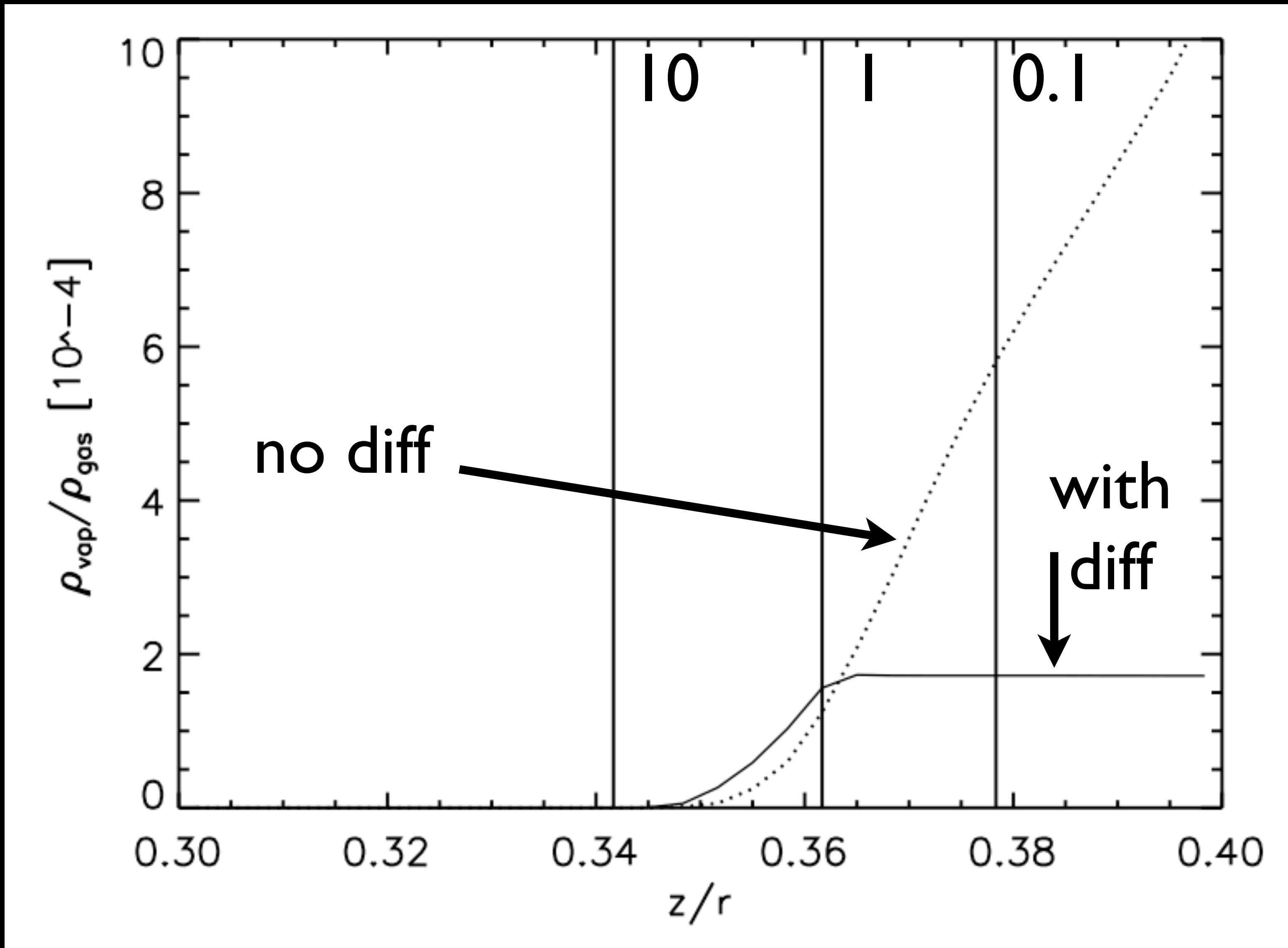
Ice layer on the grains: With diffusion



Total amount of ice

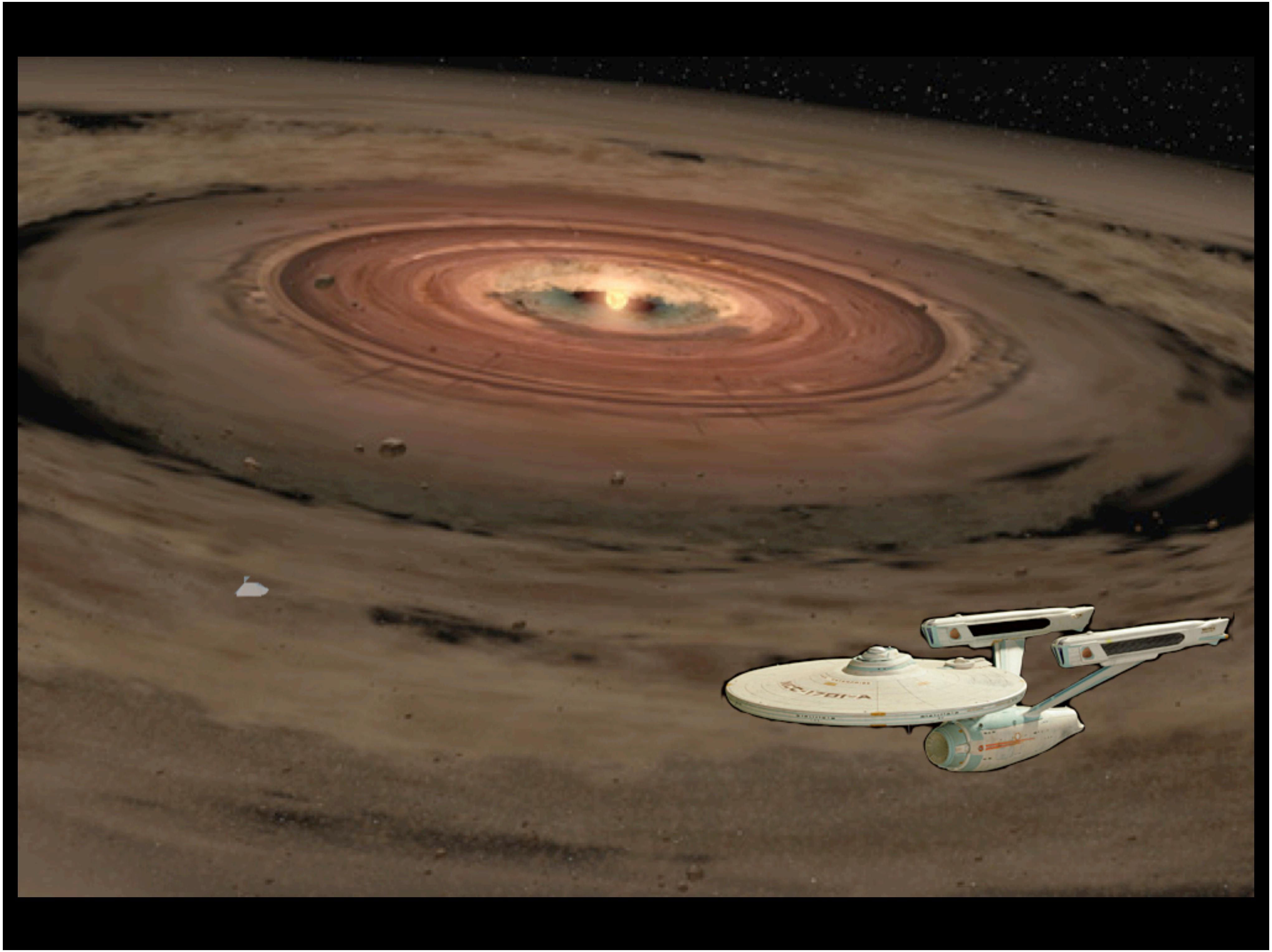


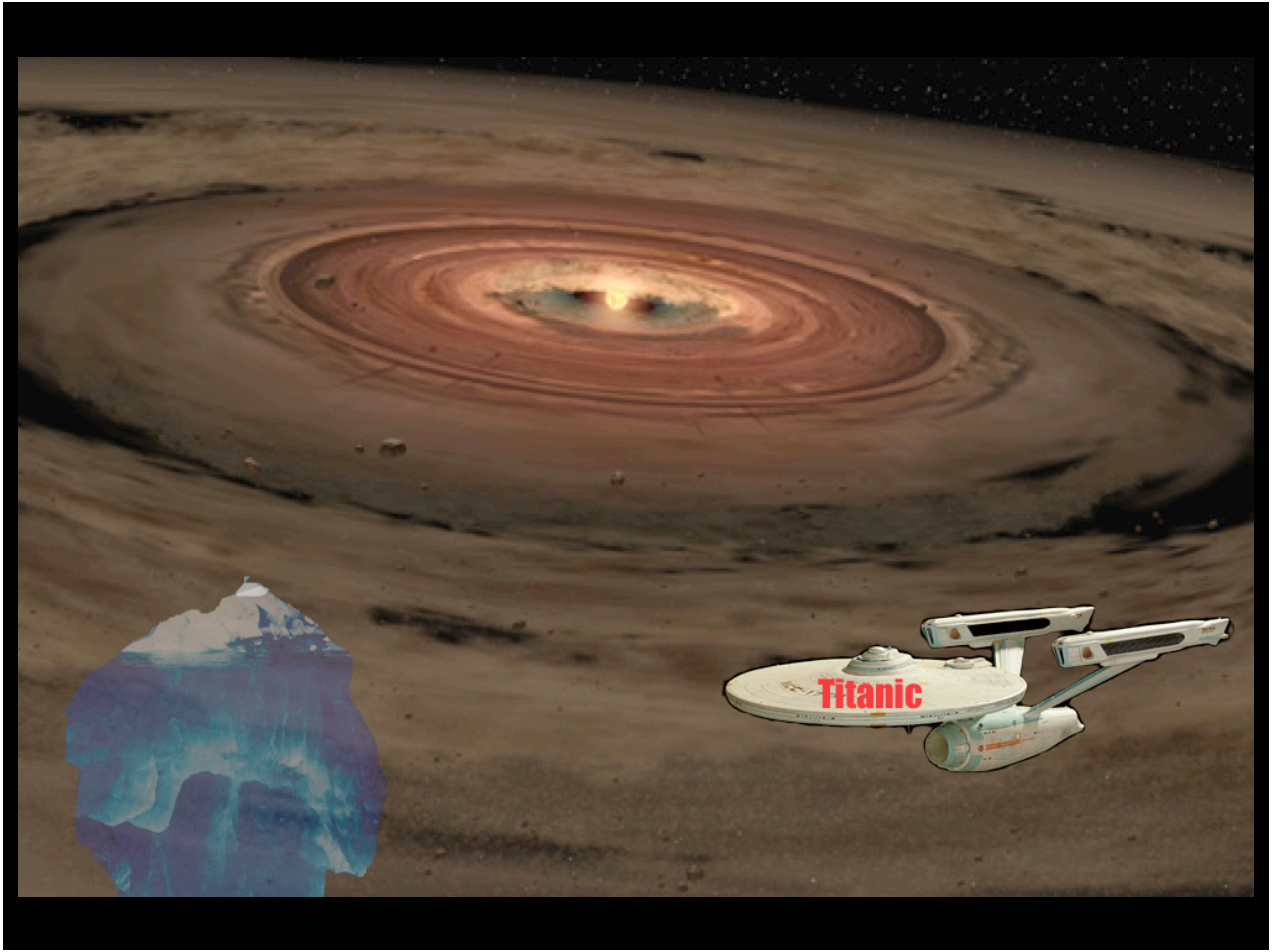
Total amount of vapor



Conclusions

- Transport effects are very important when computing the amount of molecules in freeze-out zones of a protoplanetary disk
- The ice becomes concentrated not in the midplane, but is slightly enhanced below the tau=1 surface
- Still need to include chemical model to compute the fraction $H_2O/(OH+O)$




Titanic